(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 401 375 A1

(12) EUROPEAN PATENT APPLICATION published in accordance with Art. 158(3) EPC

(21) Application number: 89908860.3

(51) Int. Cl.5: H02P 5/00

(22) Date of filing: 28.07.89

(86) International application number:
PCT/JP89/00779

(87) International publication number:
WO 90/01829 (22.02.90 90/05)

(30) Priority: 02.08.88 JP 193146/88

(43) Date of publication of application:
12.12.90 Bulletin 90/50

(84) Designated Contracting States:
CH DE FR GB LI

(71) Applicant: FANUC LTD
3580, Shibokusa Aza-Komanba Oshinomura
Minamitsuru-gun Yamanashi 401-05(JP)

(72) Inventor: KOHARI, Katsuo
35-210, Fujimi-cho 6-chome
Tachikawa-shi Tokyo 190(JP)
Inventor: KONO, Shinichi Fanuc Mansion
Harimomi 7-203
3539-1, Shibokusa Oshino-mura,
Minamitsuru-gun
Yamanashi 401-05(JP)
Inventor: FUKUKURA, Masaaki Fanuc Dai-3
Vira-karamatsu
3527-1, Shibokusa Oshino-mura,
Minamitsuru-gun
Yamanashi 401-05(JP)

(74) Representative: Billington, Lawrence Emlyn et al
Haseltine Lake & Co Hazlitt House 28,
Southampton Buildings Chancery Lane
London WC2A 1AT(GB)

(54) METHOD OF CONTROLLING SYNCHRONIZED OPERATION OF A MACHINE TOOL.

(57) A method of controlling synchronized operation of a machine tool and an apparatus therefor. In a machine tool having two main spindles (14, 15), a work (18) is gripped by the first spindle and the second spindle controlled by control circuits (19, 20) that include a speed control unit and a position control unit. When the work is to be machined under this condition, digital speed instructions are fed to the two spindles simultaneously from, for example, a numerical controller. On each of the main spindles, separation means (sw2) is controlled to separate the position control unit from the speed control unit, the synchronized operation mode is set to switch the speed instruction to the position instruction, and the digital speed instructions are processed as position instructions to carry out the same position control. Therefore, the running speed of the two main spindles are brought into synchronism with each other,

EP 0 401 375 A1

and the work is separated into two without giving excess force to the work.

DESCRIPTION

METHOD OF CONTROLLING SYNCHRONOUS OPERATION OF MACHINE TOOL

Technical Field

This invention relates to an apparatus for controlling the synchronous operation of the spindles of a machine tool having two spindles. More particularly, the invention relates to a method of controlling the synchronous operation of the machine tool, which method is so adapted that the rotational speeds of the two spindles are made to coincide with excellent precision.

Background Art

Machine tools having multiple spindle head units are widely employed as means for realizing shorter piece time when machining workpieces. Such machine tools are provided with two or more spindles for each tool rest, as seen, for example, in NC lathes, and the spindles are controlled by respective ones of independent spindle motors to shorten the time needed to mount and dismount workpieces. Alternatively, the versatility with which workpieces can be machined is raised by employing spindle motors having different capabilities.

When the grip upon a workpiece is changed among a plurality of spindles, the same velocity command is applied to the spindle motors and, at the moment the velocities coincide, a transition is made to next

machining operation without stopping the rotating workpiece.

In such a conventional machine tool in which two spindles are arranged in opposition on the same axis and the tool rests are capable of performing machining on the workpiece irrespective of which spindle it is mounted on, it is necessary that the two spindle velocities coincide reliably when the workpiece is released by one spindle and grasped by the other. If this is not accomplished, there is the danger that the workpiece will be damaged or deformed by a chuck. If the spindle motors differ, however, it is difficult to bring the two rotational velocities into perfect agreement. In addition, rotational velocities fluctuate depending upon the load, even if the velocity commands are the same.

Accordingly, the inventors have already filed an application (Japanese Patent Application No. 63-55765) for an invention in which a velocity error signal between the velocities of first and second spindles of a machine tool having these two spindles is added to a velocity command of the second spindle to correct the velocity command of the second spindle.

Synchronous operation in such case is achieved by applying the same velocity command to the spindles and limiting the torque of one of the spindles. With this method, however, an offset develops between the two spindles if the velocity command is an analog signal,

and there is the danger that the rpm's of the two spindles will shift away from each other, even if synchronism is temporarily achieved, owing to an error in a velocity feedback signal. Consequently, when cutting is performed in a state where the same workpiece is grasped simultaneously by first and second spindles and the workpiece is separated into two portions by this machining, it is necessary to raise the precision of the synchronous operation and maintain the synchronized state. In other words, if an offset in synchronism develops, an excessive force acts upon the workpiece, thus making it impossible to perform highly precise machining.

Disclosure of the Invention

The present invention has been devised in order to solve the foregoing problems and its object is to provide a novel method synchronous operation control method in which a velocity command is applied by an NC unit as a digital signal so that an offset between the rpm's of spindles can be eliminated. Further, an object of the invention is to provide an apparatus for controlling synchronous operation of spindles in which, in order to control the synchronous operation of spindles of a machine tool having two spindles, control is performed in such a manner that the positions of the two spindles become the same.

In accordance with the present invention, there can be provided a method of controlling synchronous

operation of a machine tool having first and second spindles the rotational velocities whereof are controlled by a velocity command which is a digital value, characterized by comprising a step of supplying a synchronous operation mode command when a workpiece subjected to cutting machining is grasped simultaneously by the first and second spindles, a step of inputting a velocity command to a control circuit of each spindle as a spindle position command signal in a mode set by the synchronous operation mode command, and a step of performing positional control by the control circuit of each spindle based on the position command signal, thereby synchronously rotating the two spindles.

Further, in a machine tool having two spindle motors each controlled by a control circuit which includes a velocity controller and a position controller, wherein first and second spindles are driven independently by respective ones of the spindle motors, an apparatus for controlling synchronous operation of the two spindles characterized by comprising signal input means for selecting each spindle position command signal and velocity command signal and supplying these signals to the respective control circuit, isolating means for isolating the position controller of each control circuit from the velocity controller of the control circuit, and synchronous operation mode setting means for

controlling the isolating means and changing over the velocity command to the position command.

The spindle synchronous operation control apparatus of the present invention is such that the velocity command for the two spindles is given by a common digital value. When the synchronous operation control mode has been set, this digital value is processed as a position command in each control circuit. When control is performed for synchronous operation, therefore, the positions of the two spindles are controlled so as to be the same and an offset in synchronism can be eliminated.

Brief Description of the Drawings

Fig. 1 is a view showing an example of a machine tool to which the method of the present invention can be applied and is for describing the mechanism thereof, and Fig. 2 is a control block diagram showing an example of an apparatus for controlling the synchronous operation of spindles according to the present invention.

Best Mode for Carrying Out the Invention

An embodiment of the present invention will now be described in detail with reference to the drawings.

Fig. 1 is a view showing an example of a machine tool to which the method of the present invention can be applied and is for describing the mechanism thereof. Here two spindle motors 10, 11 controlled for synchronous operation rotate a first spindle 14 and a

second spindle 15 via gear mechanisms 12, 13, respectively. The arrangement is assumed to be that of a machine tool such as a lathe, by way of example.

A chuck 16 attached to the first spindle 14 and a chuck 17 on the side of the second spindle 15 grasp the same workpiece 18, and it is in this state that cutting is carried out. The two spindles 14, 15 are rotated synchronously for a certain period of time and the workpiece 18 is cut through completely to form two parts, after which the spindles are controlled independently, in accordance with ordinary velocity control, by a velocity command supplied to spindle motor control circuits 19, 20 for the respective spindles.

To achieve this, the spindle motors 10, 11 are provided with respective velocity detectors 21, 22, and velocity signals from these velocity detectors 21, 22 are fed back to the respective spindle motor control circuits 19, 20. Furthermore, the control circuits 19, 20 of the first spindle 14 and second spindle 15 are supplied with position feedback signals from respective position detectors 23, 24, and a changeover is made to position control in response to a synchronous operation mode command.

By setting this spindle synchronous operation mode, a commanded velocity applied to the control circuits 19, 20 in the form of a digital value is processed as a position command so that positional

control of the spindles 14, 15 can be performed based on the position feedback signals from the position detectors 23, 24. As a result, the precision of the synchronous operation is improved, the synchronized state is maintained and the load on the workpiece 18 is reduced.

Fig. 2 is a control block diagram showing an example of an apparatus for controlling the synchronous operation of spindles according to the present invention. The abovementioned spindle motors 10, 11 are subjected to similar control.

Control will be described with regard to spindle motor 11 as an example. The spindle motor 11 is for rotating the second spindle 15 via the gear mechanism 13. The position feedback signal from the position detector 24 provided on the second spindle 15 enters a subtractor 25. The velocity feedback signal from the velocity detector 22 of the spindle motor 11 enters a subtractor 26, and a current feedback signal detected from a power line of the spindle motor 11 enters a subtractor 27.

The subtractor 25 is supplied with a velocity command from an NC via a switch SW1. The velocity command is in the form of a digital value and serves as a position command for the spindle motor 11. The output of the subtractor 25 is supplied to a position control circuit 28 as a position error, and the output of the position control circuit 28 is supplied, via a

switch SW2, to the subtractor 26 as a velocity command. In the absence of the synchronous operation mode command, the subtractor 26 is supplied, via the switch SW1, with the aforementioned digital value serving as a velocity command. By setting the switch SW2 to the open state at such time, the position controller of the control circuit is isolated from the velocity controller.

More specifically, by supplying the same digital value to the control circuits 19, 20 when the synchronous operation mode is commanded, the velocity error formed by the subtractor 26 causes the two spindles 14, 15 to be controlled for synchronous operation with the output of the position control circuit 28 serving as a reference at the time of synchronous operation. In a case where the velocities of the spindles are controlled independently, it will suffice to change over the switches SW1, SW2 so that the digital value will serve as a velocity command. The velocity error is applied to a velocity control circuit 29, where the error signal is subjected to proportional integration processing and then supplied to the subtractor 27 as a torque command. On the basis of an error signal from the subtractor 27, which expresses the error between the torque command and the current feedback signal, the spindle motor 11 is operated by a current control circuit 30 and a power amplifier circuit 31.

Thus, the two switches SW1, SW2 are each changed over to the contact 1 side if the synchronous operation mode command is on. At the time of ordinary independent operation, the abovementioned mode command is turned off, in which case each switch is changed over to the contact 2 side. In other words, when the synchronous operation mode command is issued, switch SW2 is closed and the velocity command for the control circuits 19, 20 of both spindles 14, 15 enters as the spindle position command signal via the switch SW1, whereby positional control is carried out.

Thus, if the synchronous operation mode command is supplied when the workpiece undergoing cutting is grasped simultaneously by the chucks 16, 17 of the first and second spindles, velocity control is carried out based on the positions of the spindles in accordance with the feedback signals from the position detectors 23, 24. As a result, even if the characteristics of the two spindle motors 10, 11 differ or there is a difference in the gear ratio between the two spindles, the spindles can be rotated synchronously in reliable fashion and the workpiece will not be subjected to excessive force.

Though an embodiment of the present invention has been described, the invention is not limited to this embodiment but can be modified in various ways without departing from the scope of the claims.

Industrial Applicability

The apparatus for controlling the synchronous operation of spindles according to the present invention is such that an offset between the rpm's of the two spindles can be eliminated reliably by detecting the positions of the spindles. Moreover, a velocity command can be changed over to a position command by applying a synchronous operation mode command. Synchronization can readily be achieved even in a case where the two spindles are operated at different gear ratios.

CLAIMS:

1. A method of controlling synchronous operation of a machine tool having first and second spindles the rotational velocities whereof are controlled by a velocity command which is a digital value, comprising:

a step of supplying a synchronous operation mode command when a workpiece subjected to cutting machining is grasped simultaneously by said first and second spindles;

a step of inputting a velocity command to a control circuit of each spindle as a spindle position command signal in a mode set by said synchronous operation mode command; and

a step of performing positional control by the control circuit of each spindle based on the position command signal, thereby synchronously rotating the two spindles.

2. In a machine tool having two spindle motors each controlled by a control circuit which includes a velocity controller and a position controller, wherein first and second spindles are driven independently by respective ones of the spindle motors, an apparatus for controlling synchronous operation of the two spindles, comprising:

signal input means for selecting each spindle position command signal and velocity command signal and supplying these signals to the respective control circuit;

isolating means for isolating the position controller of each control circuit from the velocity controller of the control circuit; and

synchronous operation mode setting means for controlling the isolating means and changing over the velocity command to the position command.

3. An apparatus for controlling synchronous operation of the spindles according to claim 1, characterized in that said velocity command is inputted as a digital value.

Fig. 1

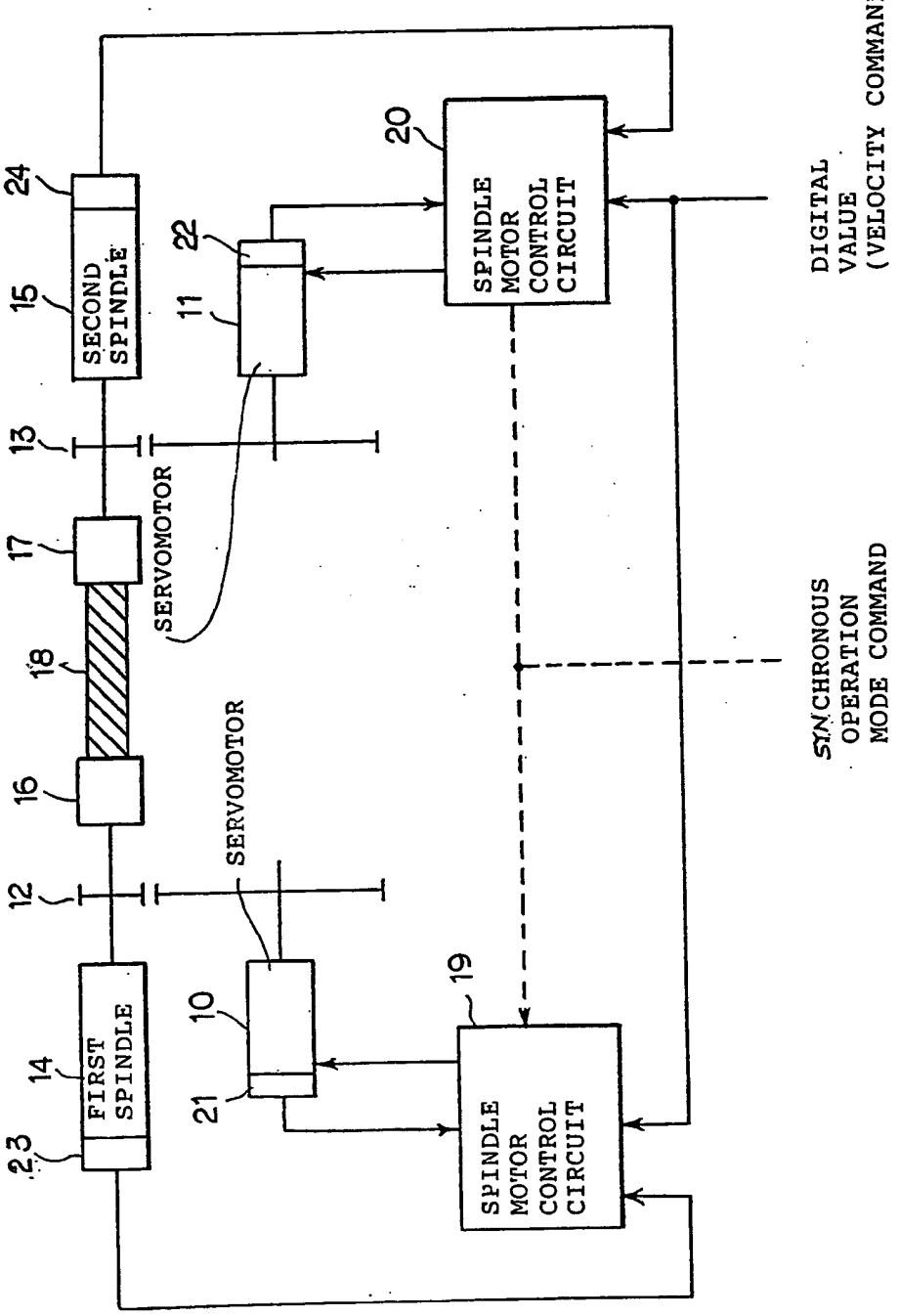
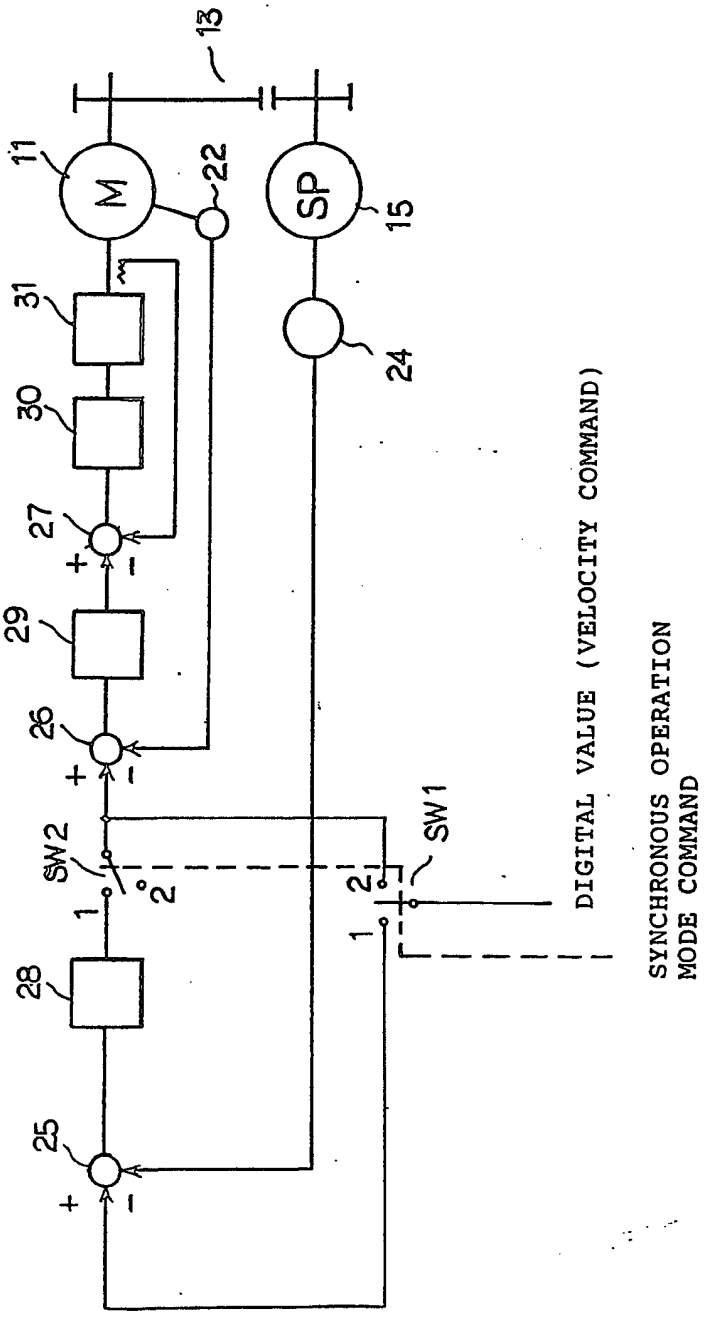


Fig. 2



INTERNATIONAL SEARCH REPORT

International Application No PCT/JP89/00779

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl[4] H02P5/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	H02P5/52

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

Jitsuyo Shinan Koho 1960 - 1988
Kokai Jitsuyo Shinan Koho 1971 - 1988

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	JP, A, 51-125817 (Mitsubishi Electric Corporation) 2 November 1976 (02. 11. 76) (Family : none)	1
Y	JP, A, 51-125817 (Mitsubishi Electric Corporation) 2 November 1976 (02. 11. 76) (Family : none)	2 - 3
Y	JP, A, 62-245312 (Canon Inc.) 26 October 1987 (26. 10. 87) (Family : none)	2 - 3

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
October 19, 1989 (19. 10. 89)	November 6, 1989 (06. 11. 89)
International Searching Authority	**Signature of Authorized Officer**
Japanese Patent Office	

Form PCT/ISA/210 (second sheet) (January 1985)

Fig. 1

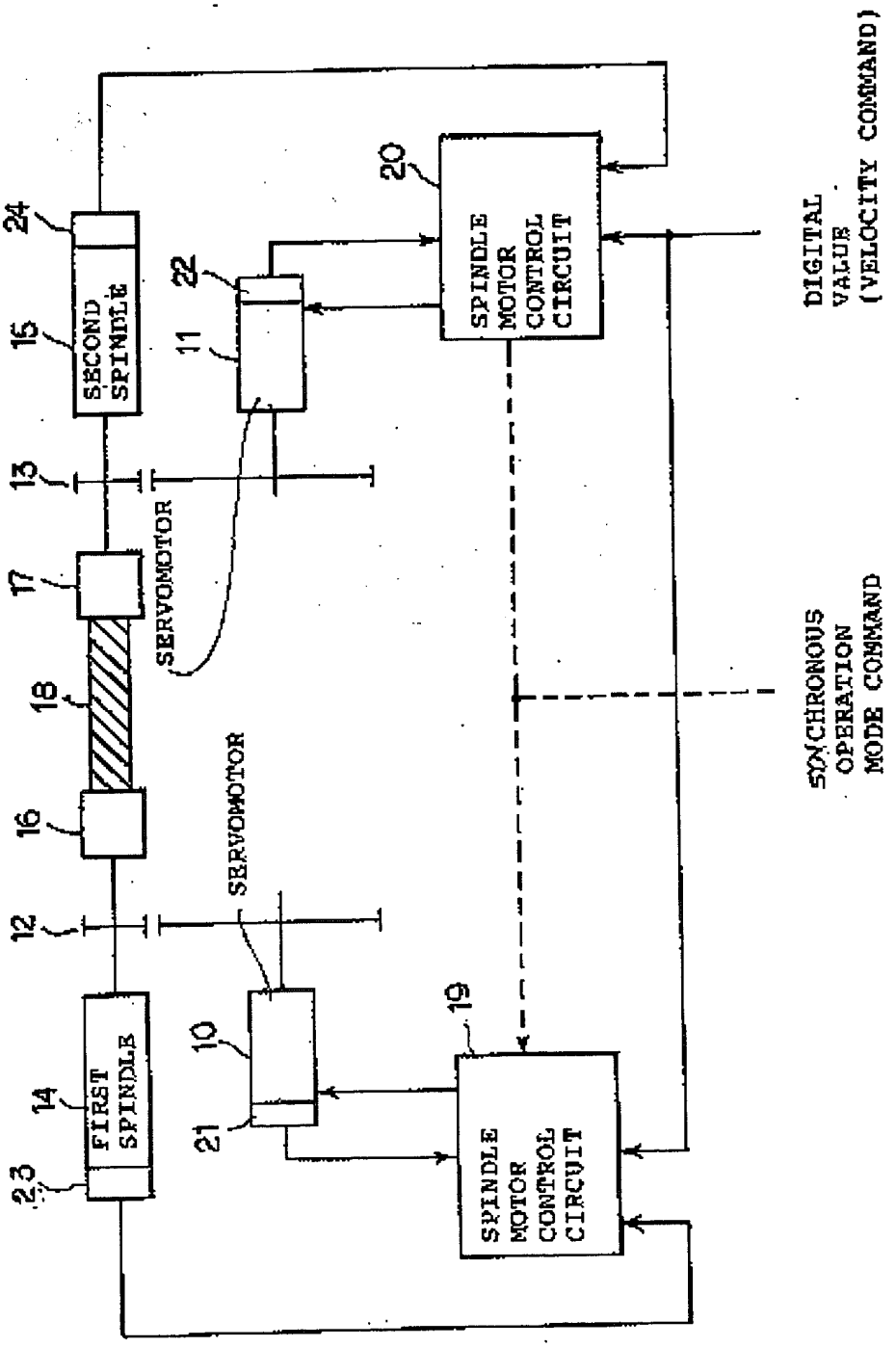
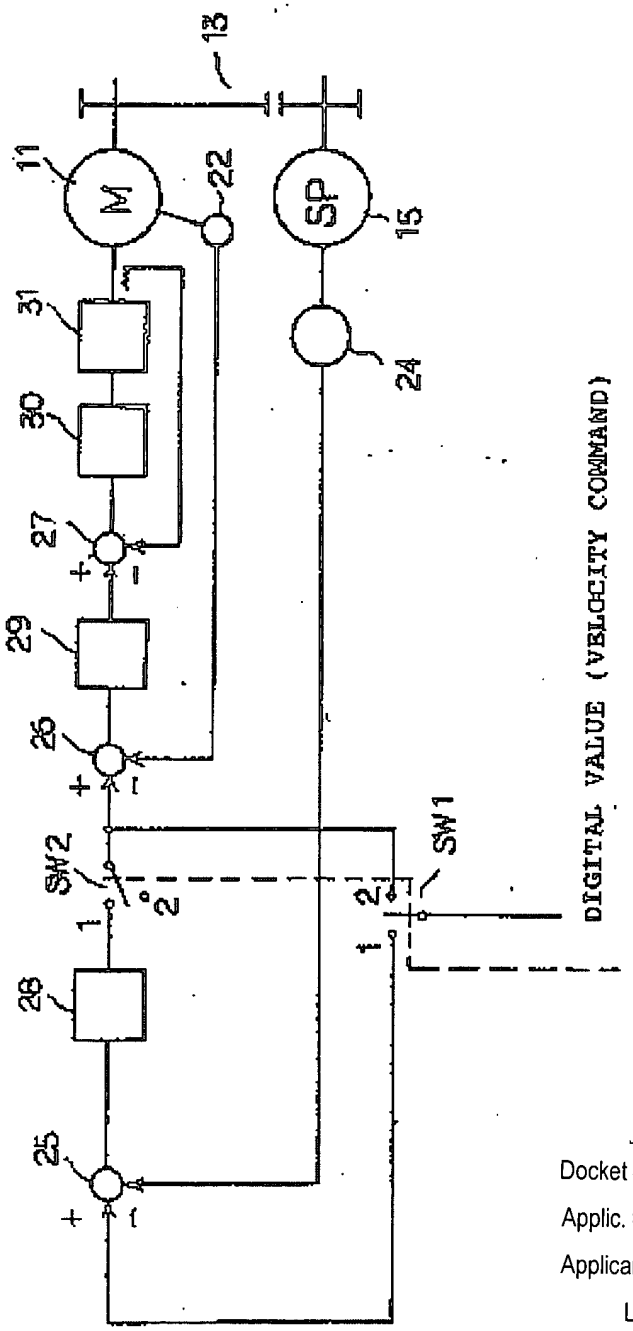


Fig.2



Docket # A-2820
Applic. # 09/848,583
Applicant: Matthes et al.

Lerner and Greenberg, P.A.
Post Office Box 2480
Hollywood, FL 33022-2480
Tel: (954) 925-1100 Fax: (954) 925-1101